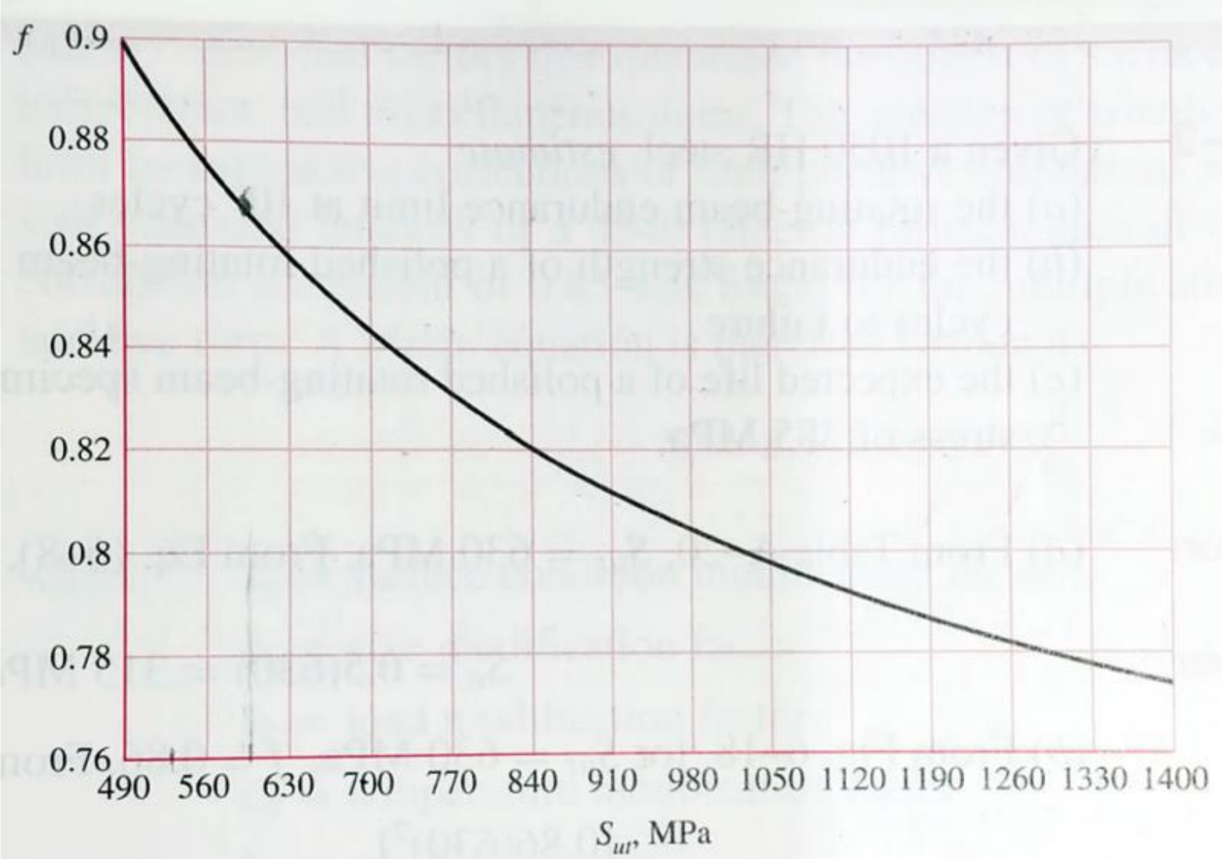
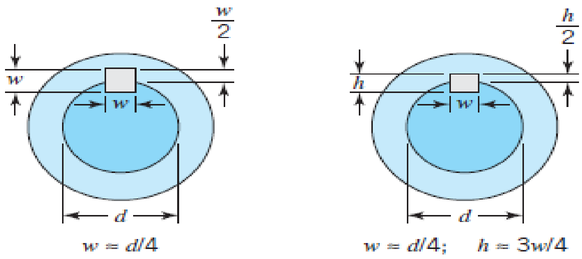


CH.6-Shaft Accessories

1- Keys



(a) Square key (b) Flat key

The shaft torque capacity can be found from $\tau = 16T/\pi d^3$ to be:

$$T = S_{sy}\frac{\pi d^3}{16} \ldots\ldots\ldots\ldots\ldots (a)$$

The torque that can be transmitted by key crushing equals (limiting stress × crushing area × radius):

$$T = F\frac{d}{2} = \sigma_{key}A_{crushing}\frac{d}{2} = S_y(\frac{t}{2}L)\frac{d}{2} \ldots\ldots\ldots\ldots (b)$$

The torque that can be transmitted by key shear equals (limiting stress × shear area × radius):

$$T = F\frac{d}{2} = \tau_{key}A_{shear}\frac{d}{2} = S_{sy}(wL)\frac{d}{2} \ldots\ldots\ldots\ldots (c)$$

$$T = S_{sy}\frac{wLd}{2} = 0.5S_y\frac{wLd}{2} = S_y\frac{wLd}{4} \ldots\ldots\ldots\ldots\ldots (d)$$

Shaft Diameter Over	To (Incl.)	Key Size w	h	Keyway Depth
8	11	2	2	1
11	14	3	2	1
		3	3	1.5
14	22	5	3	1.5
		5	5	2
22	30	6	5	2
		6	6	3
30	36	8	6	3
		8	8	5
36	44	10	6	3
		10	10	5
44	58	12	10	5
		12	12	6
58	70	16	12	5.5
		16	16	8
70	80	20	12	6
		20	20	10

7-6-2- Shaft Couplings

Table 13.1. Proportions of standard parallel, tapered and gib head keys.

Shaft diameter (mm) upto and including	*Key cross-section*		*Shaft diameter (mm) upto and including*	*Key cross-section*	
	Width (mm)	*Thickness (mm)*		*Width (mm)*	*Thickness (mm)*
6	2	2	85	25	14
8	3	3	95	28	16
10	4	4	110	32	18
12	5	5	130	36	20
17	6	6	150	40	22
22	8	7	170	45	25
30	10	8	200	50	28
38	12	8	230	56	32
44	14	9	260	63	32
50	16	10	290	70	36
58	18	11	330	80	40
65	20	12	380	90	45
75	22	14	440	100	50

13.14 Sleeve or Muff-coupling

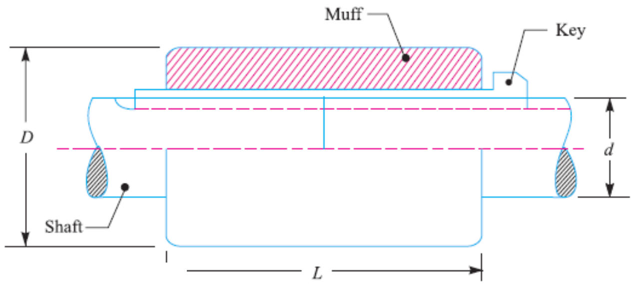
Outer diameter of the sleeve, $D = 2d + 13$ mm

and length of the sleeve, $L = 3.5\,d$

where d is the diameter of the shaft.

1. ***Design for sleeve***

The sleeve is designed by considering it as a hollow shaft.



that torque transmitted by a hollow section,

$$T = \frac{\pi}{16} \times \tau_c \left(\frac{D^4 - d^4}{D} \right) = \frac{\pi}{16} \times \tau_c \times D^3 \,(1 - k^4) \qquad \ldots (\because\ k = d/D)$$

Flange Coupling

If d is the diameter of the shaft or inner diameter of the hub, then

Outside diameter of hub,

$$D = 2\,d$$

Length of hub, $L = 1.5\,d$

Pitch circle diameter of bolts,

$$D_1 = 3d$$

Outside diameter of flange,

$$D_2 = D_1 + (D_1 - D) = 2\,D_1 - D = 4\,d$$

Thickness of flange, $t_f = 0.5\,d$

Number of bolts = 3, for d upto 40 mm

= 4, for d upto 100 mm

= 6, for d upto 180 mm

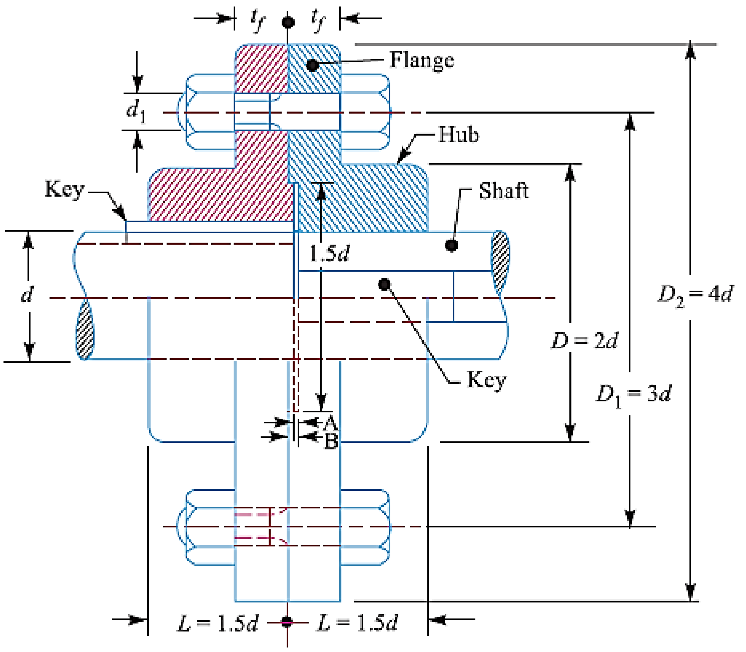


Fig. 13.12. Unprotected type flange coupling.

13.17 Design of Flange Coupling

Consider a flange coupling as shown in Fig. 13.12 and Fig. 13.13.

Let d = Diameter of shaft or inner diameter of hub,

1. *Design for hub*

The hub is designed by considering it as a hollow shaft, transmitting the same torque (T) as that of a solid shaft.

$$\therefore \qquad T = \frac{\pi}{16} \times \tau_c \left(\frac{D^4 - d^4}{D}\right)$$

The outer diameter of hub is usually taken as twice the diameter of shaft. Therefore from the above relation, the induced shearing stress in the hub may be checked.

The length of hub (L) is taken as 1.5 d.

2. *Design for key*

The key is designed with usual proportions and then checked for shearing and crushing stresses.

The material of key is usually the same as that of shaft. The length of key is taken equal to the length of hub.

3. *Design for flange*

The flange at the junction of the hub is under shear while transmitting the torque. Therefore, the troque transmitted,

T = Circumference of hub × Thickness of flange × Shear stress of flange × Radius of hub

$$= \pi\, D \times t_f \times \tau_c \times \frac{D}{2} = \frac{\pi\, D^2}{2} \times \tau_c \times t_f$$

The thickness of flange is usually taken as half the diameter of shaft. Therefore from the above relation, the induced shearing stress in the flange may be checked.

4. *Design for bolts*

The bolts are subjected to shear stress due to the torque transmitted. The number of bolts (n) depends upon the diameter of shaft and the pitch circle diameter of bolts (D_1) is taken as 3 d. We know that

$$\text{Load on each bolt} = \frac{\pi}{4}(d_1)^2\ \tau_b$$

$\therefore$ Total load on all the bolts

$$= \frac{\pi}{4}(d_1)^2\ \tau_b \times n$$

and torque transmitted, $$T = \frac{\pi}{4}(d_1)^2\ \tau_b \times n \times \frac{D_1}{2}$$

From this equation, the diameter of bolt (d_1) may be obtained. Now the diameter of bolt may be checked in crushing.

We know that area resisting crushing of all the bolts

$$= n \times d_1 \times t_f$$

and crushing strength of all the bolts

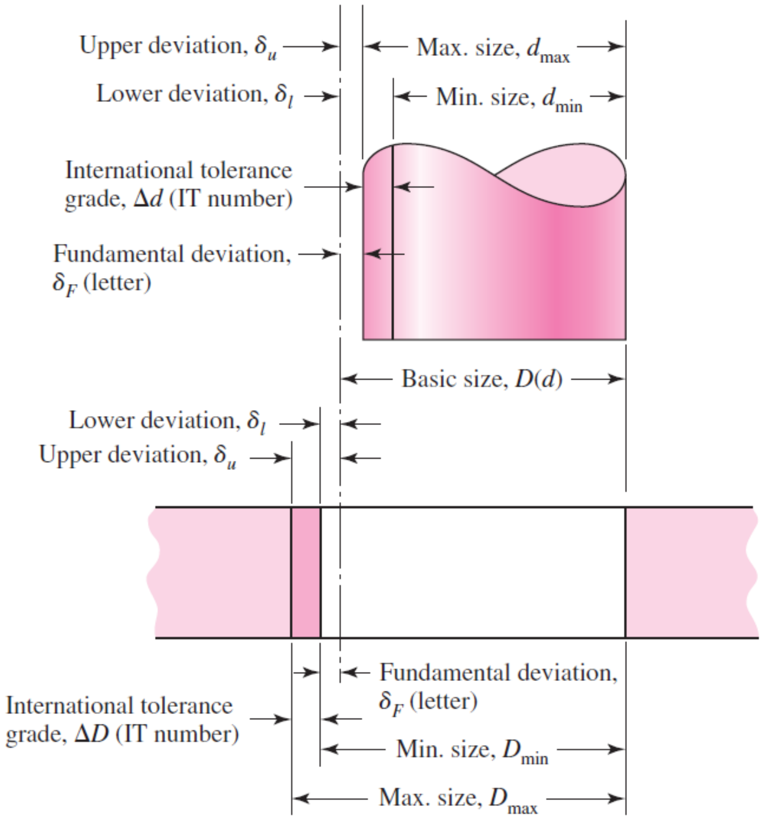
$$= (n \times d_1 \times t_f)\ \sigma_{cb}$$

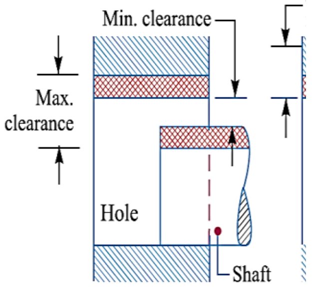
$$\therefore \text{ Torque,} \qquad T = (n \times d_1 \times t_f \times \sigma_{cb})\ \frac{D_1}{2}$$

7-6-3- Fits and Tolerances

Figure 7–20

Definitions applied to a cylindrical fit.





(*a*) Clearance fit.

Table 7–9

Descriptions of Preferred Fits Using the Basic Hole System

Source: Preferred Metric Limits and Fits, ANSI B4.2-1978. See also BS 4500.

Type of Fit	Description	Symbol
Clearance	*Loose running fit:* for wide commercial tolerances or allowances on external members	H11/c11
	Free running fit: not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures	H9/d9
	Close running fit: for running on accurate machines and for accurate location at moderate speeds and journal pressures	H8/f7
	Sliding fit: where parts are not intended to run freely, but must move and turn freely and locate accurately	H7/g6
	Locational clearance fit: provides snug fit for location of stationary parts, but can be freely assembled and disassembled	H7/h6
Transition	*Locational transition fit:* for accurate location, a compromise between clearance and interference	H7/k6
	Locational transition fit: for more accurate location where greater interference is permissible	H7/n6
Interference	*Locational interference fit:* for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements	H7/p6
	Medium drive fit: for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron	H7/s6
	Force fit: suitable for parts that can be highly stressed or for shrink fits where the heavy pressing forces required are impractical	H7/u6

Note that these quantities are all deterministic. Thus, for the hole,

$$D_{max} = D + \Delta D \qquad D_{min} = D \tag{7–36}$$

For shafts with clearance fits c, d, f, g, and h,

$$d_{max} = d + \delta_F \qquad d_{min} = d + \delta_F - \Delta d \tag{7–37}$$

For shafts with interference fits k, n, p, s, and u,

$$d_{min} = d + \delta_F \qquad d_{max} = d + \delta_F + \Delta d \tag{7–38}$$

Table A–11

A Selection of International Tolerance Grades—Metric Series (Size Ranges Are for *Over* the Lower Limit and *Including* the Upper Limit. All Values Are in Millimeters)

Source: Preferred Metric Limits and Fits, ANSI B4.2-1978. See also BSI 4500.

Basic Sizes	Tolerance Grades IT6	IT7	IT8	IT9	IT10	IT11
0–3	0.006	0.010	0.014	0.025	0.040	0.060
3–6	0.008	0.012	0.018	0.030	0.048	0.075
6–10	0.009	0.015	0.022	0.036	0.058	0.090
10–18	0.011	0.018	0.027	0.043	0.070	0.110
18–30	0.013	0.021	0.033	0.052	0.084	0.130
30–50	0.016	0.025	0.039	0.062	0.100	0.160
50–80	0.019	0.030	0.046	0.074	0.120	0.190
80–120	0.022	0.035	0.054	0.087	0.140	0.220
120–180	0.025	0.040	0.063	0.100	0.160	0.250
180–250	0.029	0.046	0.072	0.115	0.185	0.290
250–315	0.032	0.052	0.081	0.130	0.210	0.320
315–400	0.036	0.057	0.089	0.140	0.230	0.360

Table A–12

Fundamental Deviations for Shafts—Metric Series
(Size Ranges Are for *Over* the Lower Limit and *Including* the Upper Limit. All Values Are in Millimeters)

Source: Preferred Metric Limits and Fits, ANSI B4.2-1978. See also BSI 4500.

Basic Sizes	Upper-Deviation Letter c	d	f	g	h	Lower-Deviation Letter k	n	p	s	u
0–3	−0.060	−0.020	−0.006	−0.002	0	0	+0.004	+0.006	+0.014	+0.018
3–6	−0.070	−0.030	−0.010	−0.004	0	+0.001	+0.008	+0.012	+0.019	+0.023
6–10	−0.080	−0.040	−0.013	−0.005	0	+0.001	+0.010	+0.015	+0.023	+0.028
10–14	−0.095	−0.050	−0.016	−0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
14–18	−0.095	−0.050	−0.016	−0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
18–24	−0.110	−0.065	−0.020	−0.007	0	+0.002	+0.015	+0.022	+0.035	+0.041
24–30	−0.110	−0.065	−0.020	−0.007	0	+0.002	+0.015	+0.022	+0.035	+0.048
30–40	−0.120	−0.080	−0.025	−0.009	0	+0.002	+0.017	+0.026	+0.043	+0.060
40–50	−0.130	−0.080	−0.025	−0.009	0	+0.002	+0.017	+0.026	+0.043	+0.070
50–65	−0.140	−0.100	−0.030	−0.010	0	+0.002	+0.020	+0.032	+0.053	+0.087
65–80	−0.150	−0.100	−0.030	−0.010	0	+0.002	+0.020	+0.032	+0.059	+0.102
80–100	−0.170	−0.120	−0.036	−0.012	0	+0.003	+0.023	+0.037	+0.071	+0.124
100–120	−0.180	−0.120	−0.036	−0.012	0	+0.003	+0.023	+0.037	+0.079	+0.144
120–140	−0.200	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.092	+0.170
140–160	−0.210	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.100	+0.190
160–180	−0.230	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.108	+0.210
180–200	−0.240	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.122	+0.236
200–225	−0.260	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.130	+0.258
225–250	−0.280	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.140	+0.284
250–280	−0.300	−0.190	−0.056	−0.017	0	+0.004	+0.034	+0.056	+0.158	+0.315
280–315	−0.330	−0.190	−0.056	−0.017	0	+0.004	+0.034	+0.056	+0.170	+0.350
315–355	−0.360	−0.210	−0.062	−0.018	0	+0.004	+0.037	+0.062	+0.190	+0.390
355–400	−0.400	−0.210	−0.062	−0.018	0	+0.004	+0.037	+0.062	+0.208	+0.435

The Mechanics of Power Screws:

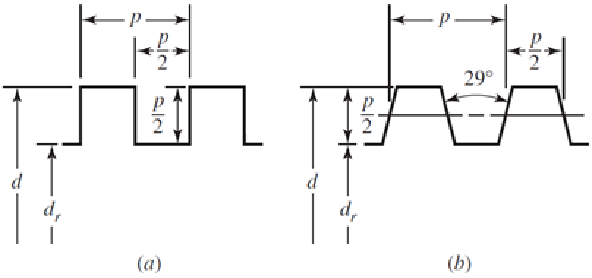


Table 8–1 Diameters and Areas of Coarse-Pitch and Fine Pitch Metric Threads.*

Nominal Major Diameter d mm	Coarse-Pitch Series: Pitch p mm	Coarse-Pitch Series: Tensile-Stress Area A_t mm²	Coarse-Pitch Series: Minor-Diameter Area A_r mm²	Fine-Pitch Series: Pitch p mm	Fine-Pitch Series: Tensile-Stress Area A_t mm²	Fine-Pitch Series: Minor-Diameter Area A_r mm²
1.6	0.35	1.27	1.07			
2	0.40	2.07	1.79			
2.5	0.45	3.39	2.98			
3	0.5	5.03	4.47			
3.5	0.6	6.78	6.00			
4	0.7	8.78	7.75			
5	0.8	14.2	12.7			
6	1	20.1	17.9			
8	1.25	36.6	32.8	1	39.2	36.0
10	1.5	58.0	52.3	1.25	61.2	56.3
12	1.75	84.3	76.3	1.25	92.1	86.0
14	2	115	104	1.5	125	116
16	2	157	144	1.5	167	157
20	2.5	245	225	1.5	272	259
24	3	353	324	2	384	365
30	3.5	561	519	2	621	596
36	4	817	759	2	915	884
42	4.5	1120	1050	2	1260	1230
48	5	1470	1380	2	1670	1630
56	5.5	2030	1910	2	2300	2250
64	6	2680	2520	2	3030	2980
72	6	3460	3280	2	3860	3800
80	6	4340	4140	1.5	4850	4800
90	6	5590	5360	2	6100	6020
100	6	6990	6740	2	7560	7470
110				2	9180	9080

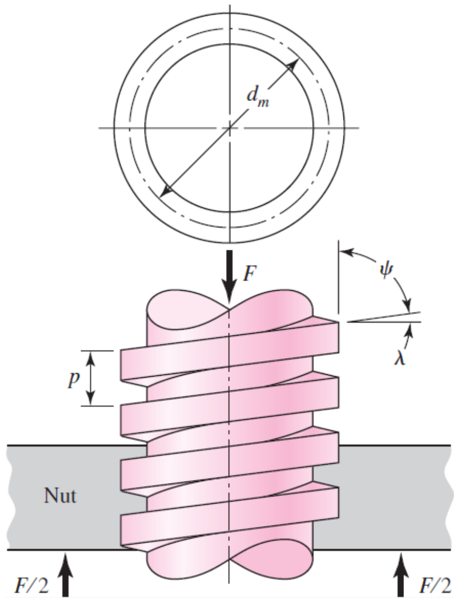


Table 8–3 Preferred Pitches for Acme Threads (الخطوة المفضلة)

d, in	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
p, in	$\frac{1}{16}$	$\frac{1}{14}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$

$$P_R = \frac{F[(l/\pi d_m) + \mu]}{1 - \mu\, l/\pi d_m} \qquad T_R = \frac{F d_m}{2}\left(\frac{\pi \mu d_m + l}{\pi d_m - \mu l}\right) \qquad P_L = \frac{F(\mu \cos\lambda - \sin\lambda)}{\cos\lambda + \mu \sin\lambda} \qquad T_L = \frac{F d_m}{2}\left(\frac{\pi \mu d_m - l}{\pi d_m + \mu l}\right)$$

$$T_0 = \frac{F d_m}{2}\left(\frac{l + \pi(0) d_m}{\pi d_m - (0) l}\right) = \frac{F d_m}{2}\left(\frac{l}{\pi d_m}\right) = \frac{F l}{2\pi} \qquad e\,\% = \frac{T_0}{T_R} = \frac{F l}{2\pi T_R} \times 100\,\% \qquad T_c = \frac{F \mu_c d_c}{2}$$

1- The shear stress τ in torsion of the screw body:

$$\tau = \frac{16T}{\pi d_r^3} \quad \dots\dots\dots (8-7)$$

2- The axial stress σ in the body

$$\sigma = \frac{4F}{\pi d_r^2} \quad \dots\dots\dots (8-8)$$

3- Bearing stress on threads

$$\sigma_B = -\frac{F}{\frac{\pi d_m n_t p}{2}} = -\frac{2F}{\pi d_m n_t p} \quad \dots\dots (8-10)$$

4- Bending stress in threads

$$\sigma_b = \frac{M}{I/c} = \frac{Fp}{4}\frac{24}{\pi d_r n_t p^2} = \frac{6F}{\pi d_r n_t p} \quad \dots\dots (8-11)$$

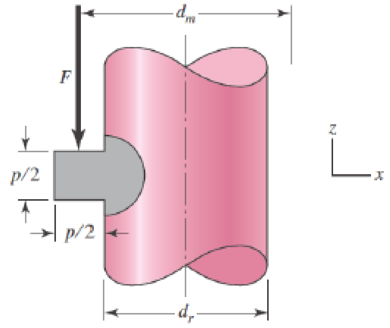


Table 8–4 Screw Bearing Pressure p_b

Screw Material	Nut Material	Safe p_b, psi	Notes
Steel	Bronze	2500–3500	Low speed
Steel	Bronze	1600–2500	10 fpm
	Cast iron	1800–2500	8 fpm
Steel	Bronze	800–1400	20–40 fpm
	Cast iron	600–1000	20–40 fpm
Steel	Bronze	150–240	50 fpm

Table 8–5 Coefficients of Friction f for Threaded Pairs

Screw Material	Nut Material			
	Steel	Bronze	Brass	Cast Iron
Steel, dry	0.15–0.25	0.15–0.23	0.15–0.19	0.15–0.25
Steel, machine oil	0.11–0.17	0.10–0.16	0.10–0.15	0.11–0.17
Bronze	0.08–0.12	0.04–0.06	—	0.06–0.09

Table 8–6 Thrust-Collar Friction Coefficients

Combination	Running	Starting
Soft steel on cast iron	0.12	0.17
Hard steel on cast iron	0.09	0.15
Soft steel on bronze	0.08	0.10
Hard steel on bronze	0.06	0.08

The Acme Threads Screws

$$T_R = \frac{F d_m}{2}\left(\frac{\pi \bar{\mu} d_m + l}{\pi d_m - \bar{\mu} l}\right)$$

Where $\bar{\mu} = \mu/\cos\alpha$ $\alpha = 14.5°$ (half tread angle)

Relation Between the Nut Speed and the Screw Speed

$$v_{nut} = \frac{n \cdot p \cdot N_s}{60} \qquad N_s = \frac{N_m}{r} \qquad P_m = \frac{P_s}{\eta_m}$$

P_m: is the motor power.

P_s: is the screw power = (lifting torque x angular velocity) = $T_R \times \omega = \frac{2\pi N_s T_R}{60}$

η_m: is the mechanical efficiency.

8-2: Threaded Fasteners البراغي

The total length of the bolt (L) is:

$$L = l + H + 2p$$

where

H: is the nut height see Fig (8-9) and table A-31in the appendix

p is the thread pitch see table (8-1)

$$A_t = \frac{\pi}{16}\left(d_p + d_r\right)^2$$

$$d_p = d - 0.649519p$$

$$d_r = d - 1.226869p$$

8-2-2 Bolt Stiffness

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} \quad \ldots\ldots\ldots\ldots(8-17)$$

where A_t = tensile-stress area (Table 8–1)

A_d = major-diameter area of fastener $A_d = \pi d^2/4$

l_d = length of unthreaded portion in grip

l_t = length of threaded portion of grip

$$L_T = \begin{cases} 2d + 6 & \text{for } L \leq 125 \text{ mm} \\ 2d + 12 & \text{for } 125 < L \leq 200 \text{ mm} \\ 2d + 25 & \text{for } L > 200 \text{ mm} \end{cases} \quad \ldots\ldots(8-14)$$

where d is the nominal diameter of the bolt

L_T is the Length of threaded portion (طول التسنين)

$l_d = L - L_T$, Length of useful unthreaded portion (طول الجزء غير المسنن)

$l_t = l - l_d$, Length of useful threaded portion : (طول التسنين داخل المنطقة)

8-2-3 Joints—Member Stiffness

$$\frac{1}{k_m} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \cdots + \frac{1}{k_i} \quad \ldots\ldots\ldots\ldots(8-18)$$

$$k_m = \frac{0.5774\pi E d}{2\ln\left(5\frac{0.5774l + 0.5d}{0.5774l + 2.5d}\right)} \quad \ldots\ldots\ldots\ldots\ldots(8-22)$$

Table 8–8

Stiffness Parameters of Various Member Materials[†]

[†]*Source:* J. Wileman, M. Choudury, and I. Green, "Computation of Member Stiffness in Bolted Connections," *Trans. ASME, J. Mech. Design*, vol. 113, December 1991, pp. 432–437.

Material Used	Poisson Ratio	Elastic GPa	Modulus Mpsi	A	B
Steel	0.291	207	30.0	0.787 15	0.628 73
Aluminum	0.334	71	10.3	0.796 70	0.638 16
Copper	0.326	119	17.3	0.795 68	0.635 53
Gray cast iron	0.211	100	14.5	0.778 71	0.616 16
General expression				0.789 52	0.629 14

8-2-4 Tension Joints - The External Load

F_i = preload

P = external tensile load

P_b = portion of P taken by bolt

P_m = portion of P taken by members

$F_b = P_b + F_i$ = resultant bolt load

$F_m = P_m - F_i$ = resultant load on members

CP= fraction of external load P carried by bolt

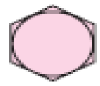
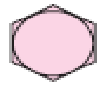
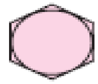
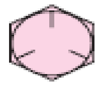
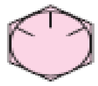
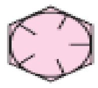
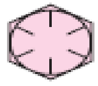
$(1 - C)P$ = fraction of external load P carried by members

$$F_b = F_i + P_b = F_i + CP \qquad F_m < 0 \qquad (8-24)$$

$$F_m = P_m - F_i = (1 - C)P - F_i \qquad (8-25)$$

Table 8–9

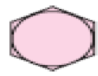
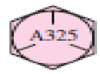
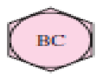
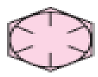
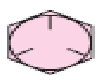
SAE Specifications for Steel Bolts

SAE Grade No.	Size Range Inclusive, in	Minimum Proof Strength,* kpsi	Minimum Tensile Strength,* kpsi	Minimum Yield Strength,* kpsi	Material	Head Marking
1	$\frac{1}{4}$–$1\frac{1}{2}$	33	60	36	Low or medium carbon	
2	$\frac{1}{4}$–$\frac{3}{4}$	55	74	57	Low or medium carbon	
	$\frac{7}{8}$–$1\frac{1}{2}$	33	60	36		
4	$\frac{1}{4}$–$1\frac{1}{2}$	65	115	100	Medium carbon, cold-drawn	
5	$\frac{1}{4}$–1	85	120	92	Medium carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
5.2	$\frac{1}{4}$–1	85	120	92	Low-carbon martensite, Q&T	
7	$\frac{1}{4}$–$1\frac{1}{2}$	105	133	115	Medium-carbon alloy, Q&T	
8	$\frac{1}{4}$–$1\frac{1}{2}$	120	150	130	Medium-carbon alloy, Q&T	
8.2	$\frac{1}{4}$–1	120	150	130	Low-carbon martensite, Q&T	

*Minimum strengths are strengths exceeded by 99 percent of fasteners.

Table 8–10

ASTM Specifications for Steel Bolts

ASTM Desig-nation No.	Size Range, Inclusive, in	Minimum Proof Strength,* kpsi	Minimum Tensile Strength,* kpsi	Minimum Yield Strength,* kpsi	Material	Head Marking
A307	$\frac{1}{4}$–$1\frac{1}{2}$	33	60	36	Low carbon	
A325, type 1	$\frac{1}{2}$–1	85	120	92	Medium carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A325, type 2	$\frac{1}{2}$–1	85	120	92	Low-carbon, martensite, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A325, type 3	$\frac{1}{2}$–1	85	120	92	Weathering steel, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
A354, grade BC	$\frac{1}{4}$–$2\frac{1}{2}$	105	125	109	Alloy steel, Q&T	
	$2\frac{3}{4}$–4	95	115	99		
A354, grade BD	$\frac{1}{4}$–4	120	150	130	Alloy steel, Q&T	
A449	$\frac{1}{4}$–1	85	120	92	Medium-carbon, Q&T	
	$1\frac{1}{8}$–$1\frac{1}{2}$	74	105	81		
	$1\frac{3}{4}$–3	55	90	58		
A490, type 1	$\frac{1}{2}$–$1\frac{1}{2}$	120	150	130	Alloy steel, Q&T	
A490, type 3	$\frac{1}{2}$–$1\frac{1}{2}$	120	150	130	Weathering steel, Q&T	

*Minimum strengths are strengths exceeded by 99 percent of fasteners.

Table 8–11 Metric Mechanical-Property Classes for Steel Bolts, Screws, and Studs*

Property Class	Size Range, Inclusive	Proof Strength,† MPa	Tensile Strength,† MPa	Yield Strength,† MPa	Material	Head Marking
4.6	M5–M36	225	400	240	Low or medium carbon	4.6
4.8	M1.6–M16	310	420	340	Low or medium carbon	4.8
5.8	M5–M24	380	520	420	Low or medium carbon	5.8
8.8	M16–M36	600	830	660	Medium carbon, Q&T	8.8
9.8	M1.6–M16	650	900	720	Medium carbon, Q&T	9.8
10.9	M5–M36	830	1040	940	Low-carbon martensite, Q&T	10.9
12.9	M1.6–M36	970	1220	1100	Alloy, Q&T	12.9

Table 8–12

Computation of Bolt and Member Stiffnesses. Steel members clamped using a $\frac{1}{2}$ in-13 NC steel bolt. $C = \frac{k_b}{k_b + k_m}$

	Stiffnesses, M lbf/in			
Bolt Grip, in	k_b	k_m	C	$1 - C$
2	2.57	12.69	0.168	0.832
3	1.79	11.33	0.136	0.864
4	1.37	10.63	0.114	0.886

$$T = KF_i d \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8-27)$$

Table 8–15 Torque Factors K for Use with Eq. (8–27)

Bolt Condition	K
Nonplated, black finish	0.30
Zinc-plated	0.20
Lubricated	0.18
Cadmium-plated	0.16
With Bowman Anti-Seize	0.12
With Bowman-Grip nuts	0.09

8-2-6 Statically Loaded Tension Joint with Preload

$$\sigma_b = \frac{F_b}{A_t} = \frac{CP + F_i}{A_t} \quad \dots\dots\dots (a)$$

$$F_m = (1 - C)P_0 - F_i = 0 \qquad (8-25)$$

1- safety factor for yielding (n_p)

$$n_p = \frac{S_p}{\sigma_b} = \frac{S_p A_t}{CP + F_i} \quad \dots\dots\dots (8-28)$$

2- Safety Factor For Separation (n_0)

$$P_0 = \frac{F_i}{1 - C}$$

$$n_s = \frac{F_i}{(1 - C)P} \quad \dots\dots\dots\dots (8-30)$$

$$F_i = \begin{cases} 0.75F_p & \text{for nonpermanent connections, reused fasteners} \\ 0.90F_p & \text{for permanent connections} \end{cases} \quad \dots\dots\dots (8-31)$$

where F_p is the proof load, obtained from the equation

$$F_p = A_p S_p \quad \dots\dots\dots\dots (8-32)$$

8-2-9 Shear Joints With Eccentric Loading (Bolt Groups)

$$\bar{x} = \frac{A_1x_1 + A_2x_2 + A_3x_3 + A_4x_4 + A_5x_5}{A_1 + A_2 + A_3 + A_4 + A_5} = \frac{\sum_1^n A_i x_i}{\sum_1^n A_i}$$

$$\bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3 + A_4y_4 + A_5y_5}{A_1 + A_2 + A_3 + A_4 + A_5} = \frac{\sum_1^n A_i y_i}{\sum_1^n A_i} \qquad (8\text{–}56)$$

$$F' = \frac{V_1}{n} \qquad F''_A = \frac{M_1 r_n}{r_A^2 + r_B^2 + r_C^2 + \cdots} \qquad (8-57)$$

Table A–17 Preferred Sizes (When a choice can be made, use one of these sizes; however, not all parts or items are available in all the sizes shown in the table.)

Decimal Inches

0.010, 0.012, 0.016, 0.020, 0.025, 0.032, 0.040, 0.05, 0.06, 0.08, 0.10, 0.12, 0.16, 0.20, 0.24, 0.30, 0.40, 0.50, 0.60, 0.80, 1.00, 1.20, 1.40, 1.60, 1.80, 2.0, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, 5.2, 5.4, 5.6, 5.8, 6.0, 7.0, 7.5, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20

Millimeters

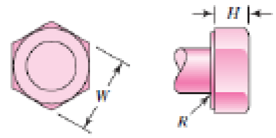
0.05, 0.06, 0.08, 0.10, 0.12, 0.16, 0.20, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.0, 1.1, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.2, 2.5, 2.8, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0, 10, 11, 12, 14, 16, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50, 60, 80, 100, 120, 140, 160, 180, 200, 250, 300

Table A–20

Deterministic ASTM Minimum Tensile and Yield Strengths for Some Hot-Rolledand Cold-Drawn Steels

1 UNS No.	2 SAE and/or AISI No.	3 Process-ing	4 Tensile Strength, MPa (kpsi)	5 Yield Strength, MPa (kpsi)	6 Elongation in 2 in, %	7 Reduction in Area, %	8 Brinell Hardness
G10060	1006	HR	300 (43)	170 (24)	30	55	86
		CD	330 (48)	280 (41)	20	45	95
G10100	1010	HR	320 (47)	180 (26)	28	50	95
		CD	370 (53)	300 (44)	20	40	105
G10150	1015	HR	340 (50)	190 (27.5)	28	50	101
		CD	390 (56)	320 (47)	18	40	111
G10180	1018	HR	400 (58)	220 (32)	25	50	116
		CD	440 (64)	370 (54)	15	40	126
G10200	1020	HR	380 (55)	210 (30)	25	50	111
		CD	470 (68)	390 (57)	15	40	131
G10300	1030	HR	470 (68)	260 (37.5)	20	42	137
		CD	520 (76)	440 (64)	12	35	149
G10350	1035	HR	500 (72)	270 (39.5)	18	40	143
		CD	550 (80)	460 (67)	12	35	163
G10400	1040	HR	520 (76)	290 (42)	18	40	149
		CD	590 (85)	490 (71)	12	35	170
G10450	1045	HR	570 (82)	310 (45)	16	40	163
		CD	630 (91)	530 (77)	12	35	179
G10500	1050	HR	620 (90)	340 (49.5)	15	35	179
		CD	690 (100)	580 (84)	10	30	197
G10600	1060	HR	680 (98)	370 (54)	12	30	201
G10800	1080	HR	770 (112)	420 (61.5)	10	25	229

Table A–29 Dimensions of Square and Hexagonal Bolts



Nominal Size, mm											
M5	8	3.58	8	3.58	0.2						
M6			10	4.38	0.3						
M8			13	5.68	0.4						
M10			16	6.85	0.4						
M12			18	7.95	0.6	21	7.95	0.6			
M14			21	9.25	0.6	24	9.25	0.6			
M16			24	10.75	0.6	27	10.75	0.6	27	10.75	0.6
M20			30	13.40	0.8	34	13.40	0.8	34	13.40	0.8
M24			36	15.90	0.8	41	15.90	0.8	41	15.90	1.0
M30			46	19.75	1.0	50	19.75	1.0	50	19.75	1.2
M36			55	23.55	1.0	60	23.55	1.0	60	23.55	1.5

Table A–31 Dimensions of Hexagonal Nuts

		Height *H*		
Nominal Size, mm	Width *W*	Regular Hexagonal	Thick or Slotted	JAM
M5	8	4.7	5.1	2.7
M6	10	5.2	5.7	3.2
M8	13	6.8	7.5	4.0
M10	16	8.4	9.3	5.0
M12	18	10.8	12.0	6.0
M14	21	12.8	14.1	7.0
M16	24	14.8	16.4	8.0
M20	30	18.0	20.3	10.0
M24	36	21.5	23.9	12.0
M30	46	25.6	28.6	15.0
M36	55	31.0	34.7	18.0

Table A–33

Dimensions of Metric Plain Washers (All Dimensions in Millimeters)

Washer Size*	Minimum ID	Maximum OD	Maximum Thickness	Washer Size*	Minimum ID	Maximum OD	Maximum Thickness
1.6 N	1.95	4.00	0.70	10 N	10.85	20.00	2.30
1.6 R	1.95	5.00	0.70	10 R	10.85	28.00	2.80
1.6 W	1.95	6.00	0.90	10 W	10.85	39.00	3.50
2 N	2.50	5.00	0.90	12 N	13.30	25.40	2.80
2 R	2.50	6.00	0.90	12 R	13.30	34.00	3.50
2 W	2.50	8.00	0.90	12 W	13.30	44.00	3.50
2.5 N	3.00	6.00	0.90	14 N	15.25	28.00	2.80
2.5 R	3.00	8.00	0.90	14 R	15.25	39.00	3.50
2.5 W	3.00	10.00	1.20	14 W	15.25	50.00	4.00
3 N	3.50	7.00	0.90	16 N	17.25	32.00	3.50
3 R	3.50	10.00	1.20	16 R	17.25	44.00	4.00
3 W	3.50	12.00	1.40	16 W	17.25	56.00	4.60
3.5 N	4.00	9.00	1.20	20 N	21.80	39.00	4.00
3.5 R	4.00	10.00	1.40	20 R	21.80	50.00	4.60
3.5 W	4.00	15.00	1.75	20 W	21.80	66.00	5.10
4 N	4.70	10.00	1.20	24 N	25.60	44.00	4.60
4 R	4.70	12.00	1.40	24 R	25.60	56.00	5.10
4 W	4.70	16.00	2.30	24 W	25.60	72.00	5.60
5 N	5.50	11.00	1.40	30 N	32.40	56.00	5.10
5 R	5.50	15.00	1.75	30 R	32.40	72.00	5.60
5 W	5.50	20.00	2.30	30 W	32.40	90.00	6.40
6 N	6.65	13.00	1.75	36 N	38.30	66.00	5.60
6 R	6.65	18.80	1.75	36 R	38.30	90.00	6.40
6 W	6.65	25.40	2.30	36 W	38.30	110.00	8.50
8 N	8.90	18.80	2.30				
8 R	8.90	25.40	2.30				
8 W	8.90	32.00	2.80				

N = narrow; R = regular; W = wide.

*Same as screw or bolt size.

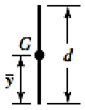
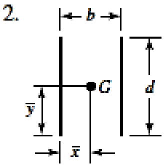
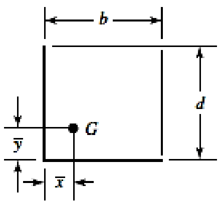
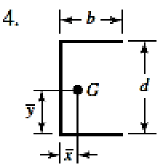
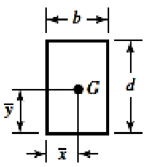
Ch. 9 Welded joints

1- Butt Welds $\sigma = \dfrac{F}{hl}$ $\tau = \dfrac{F}{hl}$

2-Fillet Welds $\tau = \dfrac{F}{tl} = \dfrac{F}{0.707hl} = \dfrac{1.414F}{hl}$

Stresses in Welded Joints in Torsion $\tau' = \dfrac{V}{A}$ $\tau'' = \dfrac{Tr}{J}$ $J = 0.707hJ_u$

Torsional Properties of Fillet Welds*

Weld	Throat Area	Location of G	Unit Second Polar Moment of Area
1. 	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$J_u = d^3/12$
2. 	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \dfrac{d(3b^2 + d^2)}{6}$
3. 	$A = 0.707h(b + d)$	$\bar{x} = \dfrac{b^2}{2(b + d)}$ $\bar{y} = \dfrac{d^2}{2(b + d)}$	$J_u = \dfrac{(b + d)^4 - 6b^2d^2}{12(b + d)}$
4. 	$A = 0.707h(2b + d)$	$\bar{x} = \dfrac{b^2}{2b + d}$ $\bar{y} = d/2$	$J_u = \dfrac{8b^3 + 6bd^2 + d^3}{12} - \dfrac{b^4}{2b + d}$
5. 	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \dfrac{(b + d)^3}{6}$
6. 	$A = 1.414\pi hr$		$J_u = 2\pi r^3$

*G is the centroid of weld group; h is weld size; plane of torque couple is in the plane of the paper; all welds are of unit width.

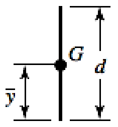
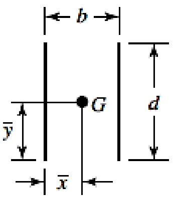
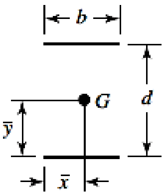
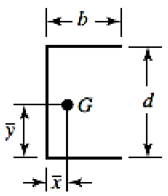
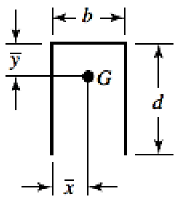
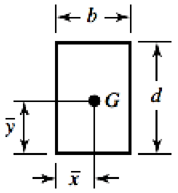
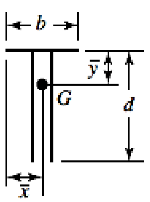
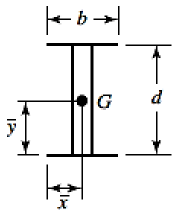
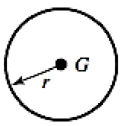
Stresses in Welded Joints in Bending $\tau' = \dfrac{V}{A}$

$$\tau'' = \frac{Mc}{I} \quad \dots\dots\dots\dots(b)$$

$$I = 0.707hI_u \quad \dots\dots.(c)$$

$$\tau = \sqrt{\tau'^2 + \tau''^2} \quad \dots\dots\dots\dots(d)$$

Bending Properties of Fillet Welds*

Weld	Throat Area	Location of G	Unit Second Moment of Area
	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$I_u = \dfrac{d^3}{12}$
	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \dfrac{d^3}{6}$
	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \dfrac{bd^2}{2}$
	$A = 0.707h(2b + d)$	$\bar{x} = \dfrac{b^2}{2b+d}$ $\bar{y} = d/2$	$I_u = \dfrac{d^2}{12}(6b+d)$
	$A = 0.707h(b + 2d)$	$\bar{x} = b/2$ $\bar{y} = \dfrac{d^2}{b+2d}$	$I_u = \dfrac{2d^3}{3} - 2d^2\bar{y} + (b+2d)\bar{y}^2$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \dfrac{d^2}{6}(3b+d)$
	$A = 0.707h(b + 2d)$	$\bar{x} = b/2$ $\bar{y} = \dfrac{d^2}{b+2d}$	$I_u = \dfrac{2d^3}{3} - 2d^2\bar{y} + (b+2d)\bar{y}^2$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \dfrac{d^2}{6}(3b+d)$
	$A = 1.414\pi hr$		$I_u = \pi r^3$

The Strength of Welded Joints

Minimum Weld-Metal Properties

AWS Electrode Number*	Tensile Strength kpsi (MPa)	Yield Strength, kpsi (MPa)	Percent Elongation
E60xx	62 (427)	50 (345)	17–25
E70xx	70 (482)	57 (393)	22
E80xx	80 (551)	67 (462)	19
E90xx	90 (620)	77 (531)	14–17
E100xx	100 (689)	87 (600)	13–16
E120xx	120 (827)	107 (737)	14

Stresses Permitted by the AISC Code for Weld Metal

Type of Loading	Type of Weld	Permissible Stress	n*
Tension	Butt	$0.60S_y$	1.67
Bearing	Butt	$0.90S_y$	1.11
Bending	Butt	$0.60–0.66S_y$	1.52–1.67
Simple compression	Butt	$0.60S_y$	1.67
Shear	Butt or fillet	$0.30S_{ut}^{\dagger}$	

*The factor of safety n has been computed by using the distortion-energy theory.

†Shear stress on base metal should not exceed $0.40S_y$ of base metal.

Fatigue Stress-Concentration Factors, K_{fs}

Type of Weld	K_{fs}
Reinforced butt weld	1.2
Toe of transverse fillet weld	1.5
End of parallel fillet weld	2.7
T-butt joint with sharp corners	2.0

Schedule A: Allowable Load for Various Sizes of Fillet Welds

	Strength Level of Weld Metal (EXX)						
	60*	70*	80	90*	100	110*	120
	Allowable shear stress on throat, MPa of fillet weld or partial penetration groove weld						
$\tau =$	124	145	165	186	207	228	248
	Allowable Unit Force on Fillet Weld, N/mm						
†$f =$	$87.67h$	$102.52h$	$116.66h$	$131.5h$	$146.35h$	$161.2h$	$175.34h$
Leg Size h, mm	Allowable Unit Force for Various Sizes of Fillet Welds N/mm						
25	2192	2563	2916	3288	3659	4030	4383
22	1929	2255	2566	2893	3220	3546	3857
20	1753	2050	2333	2630	2927	3224	3506
16	1403	1640	1866	2104	2342	2579	2805
12	1052	1230	1400	1578	1756	1934	2104
11	964	1127	1283	1447	1610	1773	1927
10	877	1025	1167	1315	1463	1612	1753
8	701	820	933	1052	1171	1290	1403
6	526	615	700	789	878	967	1052
5	438	513	583	658	732	806	877
3	263	308	350	395	439	484	526
2	175	205	233	263	293	322	351

*Fillet welds actually tested by the joint AISC-AWS Task Committee.

†$f = 0.707h\ \tau_{all}$.

Weldment Design, D412. The James F. Linc

Ch. 10 Springs

$\tau_{max} = \frac{Tr}{J} + \frac{F}{A}$, $\tau = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$, spring index $C = \frac{D}{d}$ $\tau = K_s \frac{8FD}{\pi d^3}$ $K_s = \frac{2C+1}{2C}$

The Curvature Effect: $K_B = \frac{4C+2}{4C-3}$, $\tau = K_B \frac{8FD}{\pi d^3}$, **Deflection of Helical Springs :** $k = \frac{Gd^4}{8D^3 N_a} = \frac{Gd}{8C^3 N_a}$

Table 10–1: Dimensional spring formulas. (N_a=Number of Active Coils)

Term	Type of Spring Ends: Plain	Plain and Ground	Squared or Closed	Squared and Ground
End coils, N_e	0	1	2	2
Total coils, N_t	N_a	$N_a + 1$	$N_a + 2$	$N_a + 2$
Free length, L_0	$pN_a + d$	$p(N_a + 1)$	$pN_a + 3d$	$pN_a + 2d$
Solid length, L_s	$d(N_t + 1)$	dN_t	$d(N_t + 1)$	dN_t
Pitch, p	$(L_0 - d)/N_a$	$L_0/(N_a + 1)$	$(L_0 - 3d)/N_a$	$(L_0 - 2d)/N_a$

Stability

$L_0 < 2.63\frac{D}{\alpha}$, D: the mean coil diameter, α: a constant depends on end-condition as shown in the table 10–2

Table 10–2 End-Condition Constants a for Helical Compression Springs*

End Condition	Constant α
Spring supported between flat parallel surfaces (fixed ends)	0.5
One end supported by flat surface perpendicular to spring axis (fixed); other end pivoted (hinged)	0.707
Both ends pivoted (hinged)	1
One end clamped; other end free	2

*Ends supported by flat surfaces must be squared and ground.

$S_u = \frac{A}{d^m}$, $0.35S_u \le S_{sy} \le 0.52S_u$,

Material	ASTM No.	Exponent m	Diameter, in	A, kpsi · in^m	Diameter, mm	A, MPa · mm^m	Relative Cost of Wire
Music wire*	A228	0.145	0.004–0.256	201	0.10–6.5	2211	2.6
OQ&T wire†	A229	0.187	0.020–0.500	147	0.5–12.7	1855	1.3
Hard-drawn wire‡	A227	0.190	0.028–0.500	140	0.7–12.7	1783	1.0
Chrome-vanadium wire§	A232	0.168	0.032–0.437	169	0.8–11.1	2005	3.1
Chrome-silicon wire‖	A401	0.108	0.063–0.375	202	1.6–9.5	1974	4.0
302 Stainless wire#	A313	0.146	0.013–0.10	169	0.3–2.5	1867	7.6–11
		0.263	0.10–0.20	128	2.5–5	2065	
		0.478	0.20–0.40	90	5–10	2911	
Phosphor-bronze wire**	B159	0	0.004–0.022	145	0.1–0.6	1000	8.0
		0.028	0.022–0.075	121	0.6–2	913	
		0.064	0.075–0.30	110	2–7.5	932	

Material	Elastic Limit, Percent of S_{ut} Tension	Torsion	Diameter d, in	E Mpsi	GPa	G Mpsi	GPa
Music wire A228	65–75	45–60	<0.032	29.5	203.4	12.0	82.7
			0.033–0.063	29.0	200	11.85	81.7
			0.064–0.125	28.5	196.5	11.75	81.0
			>0.125	28.0	193	11.6	80.0
HD spring A227	60–70	45–55	<0.032	28.8	198.6	11.7	80.7
			0.033–0.063	28.7	197.9	11.6	80.0
			0.064–0.125	28.6	197.2	11.5	79.3
			>0.125	28.5	196.5	11.4	78.6
Oil tempered A239	85–90	45–50		28.5	196.5	11.2	77.2
Valve spring A230	85–90	50–60		29.5	203.4	11.2	77.2
Chrome-vanadium A231	88–93	65–75		29.5	203.4	11.2	77.2
A232	88–93			29.5	203.4	11.2	77.2
Chrome-silicon A401	85–93	65–75		29.5	203.4	11.2	77.2
Stainless steel							
A313*	65–75	45–55		28	193	10	69.0
17-7PH	75–80	55–60		29.5	208.4	11	75.8
414	65–70	42–55		29	200	11.2	77.2
420	65–75	45–55		29	200	11.2	77.2
431	72–76	50–55		30	206	11.5	79.3
Phosphor-bronze B159	75–80	45–50		15	103.4	6	41.4
Beryllium-copper B197	70	50		17	117.2	6.5	44.8
	75	50–55		19	131	7.3	50.3
Inconel alloy X-750	65–70	40–45		31	213.7	11.2	77.2

*Also includes 302, 304, and 316.

Note: See Table 10–6 for allowable torsional stress design values.

Material	Maximum Percent of Tensile Strength: Before Set Removed (includes K_W or K_B)	After Set Removed (includes K_s)
Music wire and cold-drawn carbon steel	45	60–70
Hardened and tempered carbon and low-alloy steel	50	65–75
Austenitic stainless steels	35	55–65
Nonferrous alloys	35	55–65

Fatigue Loading of Helical Compression Springs :

the torsional endurance limits for infinite life of spring steels are those reported by Zimmerli,

Unpeened:

$$S_{sa} = 35 \text{ kpsi } (241 \text{ MPa}) \qquad S_{sm} = 55 \text{ kpsi } (379 \text{ MPa})$$

Peened:

$$S_{sa} = 35 \text{ kpsi } (398 \text{ MPa}) \qquad S_{sm} = 55 \text{ kpsi } (534 \text{ MPa})$$

$$S_{se} = \frac{S_{sa}}{1-\left(\frac{S_{sm}}{S_{su}}\right)^2} \quad , F_a = \frac{F_{max}-F_{min}}{2} \quad ,F_m = \frac{F_{max}+F_{min}}{2} \quad ,\tau_a = K_B\frac{8F_aD}{\pi d^3} \quad , \tau_m = K_B\frac{8F_mD}{\pi d^3}$$

(a) Gerber criterion:

$$n_f = \frac{1}{2}\left(\frac{S_{su}}{\tau_m}\right)^2 \cdot \frac{\tau_a}{S_{se}}\left[-1 + \sqrt{1 + \left(\frac{2\tau_m S_{se}}{S_{su}\tau_a}\right)^2}\right]$$

(b) Goodman line

$$S_{se} = \frac{S_{sa}}{1 - \frac{S_{sm}}{S_{su}}}$$

Name of Gauge:	American or Brown & Sharpe	Birmingham or Stubs Iron Wire	United States Standard†	Manu-facturers Standard	Steel Wire or Washburn & Moen	Music Wire	Stubs Steel Wire	Twist Drill
Principal Use:	Nonferrous Sheet, Wire, and Rod	Tubing, Ferrous Strip, Flat Wire, and Spring Steel	Ferrous Sheet and Plate, 75.4 kN/m³	Ferrous Sheet	Ferrous Wire Except Music Wire	Music Wire	Steel Drill Rod	Twist Drills and Drill Steel
7/0			12.7		12.446			
6/0	14.732		11.906		11.722	0.012		
5/0	13.119		11.112		10.935	0.127		
4/0	11.684	11.532	10.319		10.003	0.152		
3/0	10.388	10.795	9.525		9.207	0.178		
2/0	9.266	9.652	8.731		8.407	0.203		
0	8.252	8.636	7.937		7.785	0.229		
1	7.348	7.62	7.144		7.188	0.254	5.766	5.791
2	6.543	7.214	6.747		6.667	0.279	5.563	5.613
3	5.816	6.579	6.35	6.073	6.19	0.305	5.385	5.41
4	5.189	6.045	5.953	5.695	5.723	0.33	5.258	5.309
5	4.620	5.588	5.556	5.314	5.258	0.356	5.182	5.22
6	4.115	5.156	5.159	4.935	4.87	0.406	5.105	5.182
7	2.908	4.572	4.762	4.554	4.496	0.457	5.055	5.105
8	3.264	4.191	4.366	4.175	4.115	0.508	5.004	5.055
9	2.906	3.759	3.969	3.797	3.759	0.559	4.928	4.987
10	2.588	3.404	3.572	3.416	3.429	0.61	4.851	4.915
11	2.305	3.048	3.175	3.038	3.061	0.66	4.775	4.851
12	2.052	2.768	2.778	2.657	2.68	0.737	4.699	4.8
13	1.828	2.413	2.381	2.278	2.324	0.787	4.623	4.699
14	1.628	2.108	1.984	1.897	2.032	0.838	4.57	4.623
15	1.449	1.829	1.786	1.709	1.829	0.889	4.52	4.572
16	1.29	1.651	1.587	1.499	1.587	0.94	4.445	4.696
17	1.15	1.473	1.429	1.367	1.372	0.991	4.37	4.394
18	1.024	1.245	1.27	1.265	1.206	1.041	4.267	4.305
19	0.912	1.067	1.111	1.062	1.041	1.092	4.166	4.216
20	0.812	0.889	0.952	0.912	0.884	1.143	4.089	4.089
21	0.723	0.813	0.873	0.836	0.805	1.194	3.988	4.039
22	0.644	0.711	0.794	0.759	0.726	1.245	3.937	3.988
23	0.573	0.635	0.714	0.683	0.655	1.295	3.886	3.912
24	0.511	0.559	0.635	0.607	0.584	1.397	3.835	3.861
25	0.455	0.508	0.556	0.531	0.518	1.499	3.759	3.797
26	0.405	0.457	0.476	0.455	0.46	1.6	3.708	3.734
27	0.361	0.406	0.437	0.417	0.439	1.702	3.632	3.658
28	0.321	0.356	0.397	0.378	0.411	1.803	3.531	3.556
29	0.286	0.33	0.357	0.343	0.381	1.905	3.404	3.454
30	0.255	0.305	0.318	0.305	0.356	2.032	3.226	3.264
31	0.227	0.254	0.278	0.267	0.335	2.159	3.048	3.048
32	0.202	0.229	0.258	0.246	0.325	2.286	2.921	2.946
33	0.18	0.203	0.238	0.229	0.3	2.413	2.845	2.87
34	0.16	0.178	0.128	0.208	0.264		2.794	2.819
35	0.143	0.127	0.198	0.19	0.241		2.743	2.794
36	0.127	0.102	0.179	0.17	0.229		2.692	2.705
37	0.113		0.169	0.163	0.216		2.616	2.642
38	0.101		0.159	0.152	0.203		2.565	2.578
39	0.09				0.19		2.515	2.527
40	0.08				0.178		2.464	2.489

*Specify sheet, wire, and plate by stating the gauge number, the gauge name, and the decimal equivalent in parentheses.

†Reflects present average and weights of sheet steel.